ANNEX TO THE

PRELIMINARY EXAMINATION REPORT

(ARTICLE 34 AMENDMENTS)

AMENDMENT

To : Examiner of the Patent Office

1. Identification of the International Application
   PCT/JP2004/018328

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4. Item to be Amended: Claims and specification

5. Subject Matter of Amendments

(1) The expression "variance data" in the claims is amended to be "a plurality of first carrier phase accumulation data",

(2) "data received from the satellite by a mobile station" in the claims is amended to be "one or more second carrier phase accumulation data received from the

satellite by a mobile station",

(3) "associate" in the claims is amended to be "combine",

(4) claim 5 is amended to be dependent from claim 4.

(5) Section "DISCLOSURE OF THE INVENTION" on pages 3-10 is amended in response to the above amendments of the claims.

6. List of Attached Documents

(1) Replacement sheets of claims.(Page 40 - 46)

(2) Replacement sheets of pages 3 - 10.

one has to calculate the variance of the position measured by the IMU alone when the electromagnetic wave is interrupted. In addition, if the electromagnetic wave is cut off for a long time, the search space expends accordingly, and it is difficult to re-determine the integer ambiguity in a short duration.

DISCLOSURE OF THE INVENTION

Accordingly, it is a general object of the present invention to solve the above problem of the related art.

A specific object of the present invention is to provide a carrier phase GPS positioning device capable of determining and re-determining an integer ambiguity quickly and precisely, a carrier phase GPS positioning method, a carrier phase GPS positioning system, and a reference station.

According to a first aspect of the present invention, there is provided a carrier phase GPS positioning device including a first integer ambiguity estimation unit that combines a plurality of first carrier phase accumulation data in a first duration extracted from data received from a satellite by a reference station at a fixed position, with one or more second carrier phase accumulation data received from the satellite by a mobile station in a second duration shorter than the first duration, and estimates an integer ambiguity included in the second carrier phase accumulation data; and a positioning unit that determines the position of the mobile station using the integer ambiguity estimated by the first integer ambiguity estimation unit.

According to the present invention, because

the integer ambiguity is estimated by using sampling data on the mobile station side in the second duration shorter than the first duration, the time up to estimation of the integer ambiguity is shortened. The carrier phase GPS positioning device of the present invention can be implemented as a mobile station receiving data from a reference station, a reference station receiving data from a mobile station, or a device receiving data from both the reference station and the mobile station.

Preferably, abnormal values are excluded from the first carrier phase accumulation data. In addition, when reception of an electromagnetic wave emitted from the satellite is temporarily interrupted, data prior to the interruption is excluded from the first carrier phase accumulation data.

Preferably, the plurality of first carrier phase accumulation data include a plurality of carrier phase accumulation data transmitted from the satellite at a first number of times in the first duration, and the second carrier phase accumulation data in the second duration include a plurality of carrier phase accumulation data transmitted from the satellite at a second number of times in the second duration, and here the second number is less than the first number. More preferably, the second number equals one. In the latter case, single epoch positioning is possible.

In addition, preferably, after the first integer ambiguity estimation unit estimates the integer ambiguity, the positioning unit determines the position of the mobile station using data measured on the mobile station side alone.

Therefore, the amount of communication data between the mobile station and the reference station is

greatly reduced after estimation of the integer ambiguity.

In addition, preferably, the carrier phase GPS positioning device further includes a movement quantity detection unit that detects a movement of the mobile station and a movement quantity of the mobile station when the mobile station is moving, a second integer ambiguity estimation unit that, when the mobile station is at rest, estimates the integer ambiguity included in the second carrier phase accumulation data. The estimation is made based on the first carrier phase accumulation data in the period when the mobile station is at rest, and a third integer ambiguity estimation unit that, while the mobile station is moving, estimates the integer ambiguity included in the second carrier phase accumulation data while taking movement detection results into consideration.

According to the present invention, the integer ambiguity estimation units carry out the estimation processing in parallel and independently from each other. Because integer ambiguities independent from each other are estimated, by comparing and investigating the integer ambiguities, an appropriate integer ambiguity can be obtained, and this can increase precision and reliability of the positioning.

As an embodiment, after the second integer ambiguity estimation unit or the third integer ambiguity estimation unit estimates the integer ambiguity, the positioning unit determines the position of the mobile station using the integer ambiguity estimated by the second integer ambiguity estimation unit or the third integer ambiguity estimation unit instead of the integer ambiguity estimated by the first integer ambiguity estimation unit.

Further, if the mobile station is a vehicle having wheels, the movement quantity detection unit detects a movement of the vehicle based on a wheel speed sensor that detects a rotational speed of the wheels. When a slip ratio greater than a predetermined value is detected by at least the wheel speed sensor, the integer ambiguity estimation processing by the third integer ambiguity estimation unit is initialized, and the positioning unit determines the position of the mobile station using the integer ambiguity estimated by the first integer ambiguity estimation unit until the third integer ambiguity estimation unit estimates or re-estimates the integer ambiguity.

But when the integer ambiguity has been estimated by the second integer ambiguity estimation unit, the integer ambiguity estimated by the second integer ambiguity estimation unit may be used for determining the position of the mobile station.

Because the third integer ambiguity estimation unit takes movement quantity detection results into consideration, even when the mobile station is moving, it is possible to estimate the integer ambiguity at high precision.

In addition, preferably, when plural reference stations are present in a communication region, a reference station is selected which is able to communicate with more satellites in common with the satellite communicating with the mobile station, and the first carrier phase accumulation data related to the selected reference station are used. In addition, when there are plural reference stations able to communicate with the same number of satellites, a reference station is selected which has the highest minimum reception

strength of signals from the satellites. Further, when plural reference stations, which receive signals from plural common satellites and the signal reception strength of each of the common satellites exceeds a predetermined value, are present in a communication region, a reference station is selected which is closest to the mobile station, and the first carrier phase accumulation data related to the selected reference station are used.

Therefore, even the reference station changes along with the movement of the mobile station, reduction of the integer ambiguity estimation precision is preventable.

The carrier phase GPS positioning device of the above inventions may be installed in the navigation device of a vehicle acting as a mobile station, or other movable objects such as a working robot, a mobile phone, and a PDA, or alternatively, in a facility capable of bi-directional communication with the mobile station.

According to a second aspect of the present invention, there is provided a carrier phase GPS positioning method, including the steps of combining a plurality of first carrier phase accumulation data in a first duration extracted from data received from a satellite by a reference station at a fixed position, with one or more second carrier phase accumulation data received from the satellite by a mobile station in a second duration shorter than the first duration, and estimating an integer ambiguity included in the second carrier phase accumulation data; and determining the position of the mobile station using the estimated integer ambiguity.

According to a third aspect of the present

invention, there is provided a carrier phase GPS positioning method including the steps of acquiring a carrier phase accumulation value at one time on the mobile station side; acquiring a plurality of carrier phase accumulation values at a plurality of times prior to the one time on the reference station side; combining the carrier phase accumulation values on the reference station side at the plural times, with a carrier phase accumulation value on the mobile station side at the one time, and estimating an integer ambiguity included in the carrier phase accumulation value of signals transmitted from the satellite received by the mobile station.

According to a fourth aspect of the present invention, there is provided a carrier phase GPS positioning system including a reference station that extracts a plurality of first carrier phase accumulation data in a first duration based on received data from a satellite; a carrier phase GPS positioning device including a first integer ambiguity estimation unit that combines the first carrier phase accumulation data with one or more second carrier phase accumulation data received from the satellite by a mobile station in a second duration shorter than the first duration, and estimates an integer ambiguity included in the second carrier phase accumulation data; a positioning unit that determines the position of the mobile station using the estimated integer ambiguity; and a communication path that enables communication between the carrier phase GPS positioning device and the reference station.

According to a fifth aspect of the present invention, there is provided a reference station that extracts a plurality of first carrier phase accumulation data in a predetermined duration based on received data

from a satellite, and transmits the first carrier phase accumulation data to a carrier phase GPS positioning device including an estimation unit that combines the first carrier phase accumulation data with one or more second carrier phase accumulation data received from the satellite by a mobile station in a second duration shorter than the predetermined duration, and estimates an integer ambiguity included in the second carrier phase accumulation data; and a positioning unit that determines the position of the mobile station using the estimated integer ambiguity.

According to a sixth aspect of the present invention, there is provided a reference station including an acquisition unit that acquires a carrier phase accumulation value at one time on a mobile station side; an integer ambiguity estimation unit that combines a plurality of carrier phase accumulation values at a plurality of times prior to the one time on the reference station side with the carrier phase accumulation value on the mobile station side, and estimates an integer ambiguity included in the carrier phase accumulation value on the mobile station side; a positioning unit that determines the position of the mobile station using the integer ambiguity estimated by the integer ambiguity estimation unit; and a transmission unit that transmits the position detected by the positioning unit to the mobile station.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects, features, and advantages of the present invention will become more apparent from the following detailed description of preferred embodiments given with reference to the

accompanying drawings, in which:

FIG. 1 is a schematic view of a carrier phase GPS positioning device according to the present invention;

FIG. 2 is a diagram showing a configuration of the carrier phase GPS positioning device in FIG. 1;

FIG. 3 is a block diagram showing an embodiment of a carrier phase GPS positioning device 34 installed in the mobile station 30 according to the present invention;

FIG. 4 is a view illustrating the definitions of coordinate systems used in descriptions;

FIG. 5 is a flowchart illustrating the method of determining the integer ambiguity in the carrier phase GPS positioning device 34 according to the present embodiment;

FIG. 6 is a flowchart illustrating the optional processing subsequent to the routine in FIG. 5;

FIG. 7 is a flowchart illustrating an operation of determining the integer ambiguity by the time-series determination method of the related art, which is performed in parallel to the routine in FIG. 5

CLAIMS

1. (amended) A carrier phase GPS positioning device, comprising:

a first integer ambiguity estimation unit that combines a plurality of first carrier phase accumulation data in a first duration extracted from data received from a satellite by a reference station at a fixed position, with one or more second carrier phase accumulation data received from the satellite by a mobile station in a second duration shorter than the first duration, and estimates an integer ambiguity included in the second carrier phase accumulation data; and

a positioning unit that determines the position of the mobile station using the integer ambiguity estimated by the first integer ambiguity estimation unit.

2. (amended) The carrier phase GPS positioning device as claimed in claim 1, wherein abnormal values are excluded from the first carrier phase accumulation data.

3. (amended) The carrier phase GPS positioning device as claimed in claim 1, wherein when reception of an electromagnetic wave emitted from the satellite is temporarily interrupted, data prior to the interruption is excluded from the first carrier phase accumulation data.

4. (amended) The carrier phase GPS positioning device as claimed in claim 1, wherein

the plurality of first carrier phase accumulation data in the first duration includes a plurality of carrier phase accumulation data transmitted from the satellite at a first number of times in the first duration; and

the second carrier phase accumulation data in the second duration include a plurality of carrier phase accumulation data transmitted from the satellite at a second number of times in the second duration, said second number being less than the first number.

5. (amended) The carrier phase GPS positioning device as claimed in claim 4, wherein the second number equals one.

6. (original) The carrier phase GPS positioning device as claimed in claim 3, wherein after the first integer ambiguity estimation unit estimates the integer ambiguity, the positioning unit determines the position of the mobile station using data measured on the mobile station side alone.

7. (amended) The carrier phase GPS positioning device as claimed in claim 4, further comprising:

a movement quantity detection unit that detects a movement of the mobile station and a movement quantity of the mobile station when the mobile station is moving;

a second integer ambiguity estimation unit that, when the mobile station is at rest, estimates the integer ambiguity included in the second carrier phase accumulation data , said estimation being made based on the first carrier phase accumulation data and the second carrier phase accumulation data in the period when the mobile station is at rest; and

a third integer ambiguity estimation unit that, while the mobile station is moving, estimates the integer ambiguity included in the second carrier phase accumulation data while taking movement quantity detection

results into consideration.

8. (original) The carrier phase GPS positioning device as claimed in claim 7, wherein

after the second integer ambiguity estimation unit or the third integer ambiguity estimation unit estimates the integer ambiguity, the positioning unit determines the position of the mobile station using the integer ambiguity estimated by the second integer ambiguity estimation unit or the third integer ambiguity estimation unit instead of the integer ambiguity estimated by the first integer ambiguity estimation unit.

9. (original) The carrier phase GPS positioning device as claimed in claim 7, wherein

the mobile station is a vehicle having wheels;

the movement quantity detection unit detects a movement of the vehicle based on a wheel speed sensor that detects a rotational speed of the wheels;

when a slip ratio greater than a predetermined value is detected by at least the wheel speed sensor, the integer ambiguity estimation processing by the third integer ambiguity estimation unit is initialized, and the positioning unit determines the position of the mobile station using the integer ambiguity estimated by the first integer ambiguity estimation unit until the third integer ambiguity estimation unit estimates or re-estimates the integer ambiguity.

10. (amended) The carrier phase GPS positioning device as claimed in claim 1, wherein

when a plurality of reference stations is present in a communication region, the reference station

is selected which is able to communicate with more satellites in common with the satellite communicating with the mobile station, and

the first carrier phase accumulation data related to the selected reference station is used.

11. (original) The carrier phase GPS positioning device as claimed in claim 10, wherein when there are plural of the reference stations able to communicate with the same number of the satellites, the reference station is selected which has the highest minimum reception strength of signals from the satellites.

12. (amended) The carrier phase GPS positioning device as claimed in claim 1, wherein

when a plurality of reference stations, which receives signals from a plurality of common satellites and the signal reception strength with each of the common satellites exceeds a predetermined value, is present in a communication region, the reference station is selected which is closest to the mobile station, and

the first carrier phase accumulation data related to the selected reference station is used.

13. (amended) A carrier phase GPS positioning method, comprising the steps of:

combining a plurality of first carrier phase accumulation data in a first duration extracted from data received from a satellite by a reference station at a fixed position, with one or more second carrier phase accumulation data received from the satellite by a mobile station in a second duration shorter than the first duration, and estimating an integer ambiguity included in

the second carrier phase accumulation data; and

determining the position of the mobile station using the estimated integer ambiguity.

14. (amended) A carrier phase GPS positioning method, comprising the steps of:

acquiring a carrier phase accumulation value at one time on the mobile station side;

acquiring a plurality of carrier phase accumulation values at a plurality of times prior to the one time on the reference station side;

combining the carrier phase accumulation values on the reference station side at the plural times, with a carrier phase accumulation value on the mobile station side at the one time, and estimating an integer ambiguity included in the carrier phase accumulation value of signals transmitted from the satellite received by the mobile station.

15. (amended) A carrier phase GPS positioning system, comprising:

a reference station that extracts a plurality of first carrier phase accumulation data in a first duration based on received data from a satellite;

a carrier phase GPS positioning device including a first integer ambiguity estimation unit that combines the first carrier phase accumulation data with one or more second carrier phase accumulation data received from the satellite by a mobile station in a second duration shorter than the first duration, and estimates an integer ambiguity included in the second carrier phase accumulation data; and a positioning unit that determines the position of the mobile station using

the estimated integer ambiguity; and

a communication path that enables communication between the carrier phase GPS positioning device and the reference station.

16. (amended) A reference station that extracts a plurality of first carrier phase accumulation data in a predetermined duration based on received data from a satellite, and transmits the first carrier phase accumulation data to a carrier phase GPS positioning device including an estimation unit that combines the first carrier phase accumulation data with one or more second carrier phase accumulation data received from the satellite by a mobile station in a second duration shorter than the predetermined duration, and estimates an integer ambiguity included in the second carrier phase accumulation data ; and a positioning unit that determines the position of the mobile station using the estimated integer ambiguity.

17. (amended) A reference station, comprising:

an acquisition unit that acquires a carrier phase accumulation value at one time on a mobile station side;

an integer ambiguity estimation unit that combines a plurality of the carrier phase accumulation values at a plurality of times prior to the one time on the reference station side with the carrier phase accumulation value on the mobile station side, and estimates an integer ambiguity included in the carrier phase accumulation value on the mobile station side; and

a positioning unit that determines the position of the mobile station using the integer ambiguity

estimated by the integer ambiguity estimation unit; and

a transmission unit that transmits the position detected by the positioning unit to the mobile station.